Information on Atlantic Sturgeon for the Refinement of Dissolved Oxygen Criteria in Mount Hope Bay and the Taunton River Estuary

Internal Draft

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1 Background

The Massachusetts Department of Environmental Protection (MassDEP) has initiated a review of its saltwater DO criteria in Mount Hope Bay and the Taunton River Estuary to inform the potential refinement of these criteria. As part of this process, a draft report entitled "Consideration for Refinement of Dissolved Oxygen Criteria in Mount Hope Bay and Taunton River Estuary" (the Mount Hope Bay Report) dated June 2017 was prepared for the MassDEP by Tetra Tech, Inc. and Normandeau Associates, Inc. The United States Environmental Protection Agency (USEPA) has provided preliminary comments on the draft report including specific comments on the dissolved oxygen required for Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) and how the preliminary calculated Criterion Minimum Concentration (CMC) and Criterion Continuous Concentration (CCC) values will be protective to this species. To help address these comments, MassDEP requested that a white paper be prepared to provide information on Atlantic Sturgeon life history, occurrence in the study area, and dissolved oxygen requirements.

2 General Life History

Atlantic Sturgeon is a long-lived, late maturing, estuarine dependent, anadromous fish that ranges from Hamilton River, Labrador, and George River, Ungava Bay, to Port Canaveral and Hutchinson Island, Florida (Collette & Klein-MacPhee 2002, ASSRT 2007). Thirty-five rivers in the United States have been confirmed to have had a historical spawning population; currently 32 rivers contain Atlantic Sturgeon, with at least 24 having a spawning population. Many of these populations are at historic lows (ASSRT 2007, Hilton et al. 2016). On February 6, 2012, the NMFS listed five distinct population segments (DPSs) of Atlantic Sturgeon under the Endangered Species Act; the New York Bight, Chesapeake Bay , Carolina, and South Atlantic populations were listed as endangered, while the Gulf of Maine population was listed as threatened (77 FR 5880). Critical habitat for these Atlantic Sturgeon DPSs was designated on August 17, 2017 (82 FR 39160). Atlantic Sturgeon is also listed as endangered species by the State of Massachusetts under the Massachusetts Endangered Species Act (NHESP 2015).

Atlantic Sturgeon utilizes a wide variety of habitats. Adults generally spawn in the tidal freshwater areas of estuaries above the salt front (Van Eenennaam et al. 1996, Bain et al. 2000, Greene et al. 2009). Atlantic Sturgeon requires silt-free hard bottom substrates such as gradient boulder, bedrock, cobble-gravel, clay, and coarse sand to spawn adhesive eggs (Bain et al. 2000, Collins et al. 2000, Collette & Klein-MacPhee 2002, Greene et al. 2009). Atlantic Sturgeon spawning has been documented in water from 3 – 27 meters (m) deep with temperatures that range from 13° C to 26° C (Bain et al. 2000, Hatin et al. 2002, Greene et al. 2009). Spawning in Massachusetts waters occurs from May through June (Stone et al. 1994, Hartel et al. 2002, NHESP 2015). Subadult and adult Atlantic Sturgeon were reported to rarely occur year round in Narragansett Bay (Stone et al. 1994).

Eggs hatch in 94 to 140 hours at water temperatures of 20° C and 18° C, respectively and in 60 hours at temperatures between 20° C to 21° C (Mohler 2003, Greene et al. 2009). Atlantic

Sturgeon larvae hatch at approximately 7 millimeters (mm) total length (TL). This pelagic yolksac larval stage lasts approximately 10 days and then the larvae settle to the bottom near the spawning area. Larvae Atlantic Sturgeon are less than 30 mm TL and less than 4 weeks old (Smith et al. 1980, Bath et al. 1981, Greene et al. 2009). Larvae remain in deep river channels near spawning habitat upstream of the salt front and have been collected at depths of 9 to 20 m (29 to 66 ft; Greene et al. 2009). YOY (< 41 cm TL) and juvenile sturgeon (> 41 cm to <76 cm TL) are found over sand, mud, cobble, rocks and transitional substrates (Greene et al. 2009, GARFO 2017). Juvenile sturgeon remain in their natal rivers for 1 to 6 year before migrating to marine waters (Secor et al. 2000, Greene et al. 2009, Dunton et al. 2016). Juveniles have been reported at salinities from 0 to 27.5 ppt.

Subadult (> 76 cm to < 150 cm TL) Atlantic Sturgeon emigrate out of their natal estuarine habitats in the fall and migrate long distances in the marine environment (Greene et al. 2009, GARFO 2017). Subadult and adult (> 150 cm TL) Atlantic Sturgeon frequently congregate in upper estuary habitats around the saltwater interface (Greene et al. 2009). In estuarine habitats, non-spawning adults have been observed in shallow to moderately shallow areas (1.5m to 60 m) with fine mud, sand, pebble, and shell substrate (Greene et al. 2009). In nearshore Atlantic coastal shelf areas subadult and non-spawning adult Atlantic Sturgeon have been documented in moderately shallow (7 m to 50 m) sand and gravel habitats (Stein et al. 2004a, Laney et al. 2007, Greene et al. 2009, Dunton et al. 2010). Studies have shown that Atlantic Sturgeon aggregate in areas off the Penobscot River, the Kennebec System (Kennebec, Androscoggin, and Sheepscot Rivers), southwest Long Island, along the New Jersey coast, off Delaware Bay, and off Chesapeake Bay (Stein et al. 2004b, Dunton et al. 2010, Erickson et al. 2011, Damon-Randall et al. 2013). Seasonal depth distribution patterns were observed in these studies, with sturgeon occupying the deepest waters during the winter and the shallowest waters during summer and early fall (Dunton et al. 2010, Fernandes et al. 2010, Erickson et al. 2011, Damon-Randall et al. 2013). The lowest numbers of Atlantic Sturgeon caught in coastal shelf areas occurs during the summer (Dunton et al. 2010).

Atlantic Sturgeon age of sexually maturity varies with latitude, southern populations mature faster than northern populations with males maturing earlier than females (Greene et al. 2009, Hilton et al. 2016). In South Carolina, males mature as early as 5 years of age and females as early as 7 years (Greene et al. 2009). In the Chesapeake Bay, males mature at approximately 10 years of age and females at about 15 years (Balazik et al. 2012). In the Hudson River, males mature between 8-19 years of age, and females between 15-20 years of age (Bain 1997, Hilton et al. 2016). In the St. John River, Canada, males mature between 16–24 years of age and females between 17–28 years of age (Stewart et al. 2015, Bradford et al. 2016, Hilton et al. 2016). The maximum recorded age for Atlantic Sturgeon is 60 years, based on a 267 cm TL individual collected from the St. Lawrence River (Collette & Klein-MacPhee 2002).

Adult Atlantic Sturgeon make seasonal migrations to and from freshwater spawning habitats. Spawning migrations to freshwater habitats occur in late winter to early summer (Stein et al. 2004a). Atlantic Sturgeon appear to undergo large-scale southerly fall migrations and northerly spring migrations (Dovel and Berggren 1983, Dunton et al. 2010). Sturgeon use marine habitat for foraging before returning to natal rivers to spawn (Dunton et al. 2010). Diet prey items include polychaetes, amphipods, isopods, decapods, mollusks, and sand lance (*Ammodytes* spp.; Scott and Scott 1988, Johnson et al. 1997, Dunton et al. 2010). A summary of environmental habitat parameters is presented in Appendix A.

3 Mount Hope Bay and the Taunton River

Historically, Atlantic Sturgeon occurred in Narragansett Bay and was known to spawn in the Taunton River at the turn of the 20th century (Tracy 1905). In 1905, Atlantic Sturgeon was common in traps set off Sakonnet from May through November, though rare in the upper part of Narragansett Bay. Sturgeons were anecdotally more common in 1885 off Sakonnet when 5 or 6 individuals were caught in the traps at a time (Tracey 1905). Buerkett and Kynard (1993) surveyed the Taunton River for both Atlantic and Shortnose Sturgeon in 1991 and 1992 using gill nets set from Mount Hope Bay to river mile 21. They collected three Atlantic Sturgeon, all three fish were dead from gill netting and in poor condition. One fish was caught in mid-July in 1991 near Plain Street Bridge in Taunton, and two fish (910 mm and 1000 mm TL) were caught in mid-June in 1992 just downstream of the confluence with Three Mile River. The authors concluded that these sturgeons were non-natal subadult strays probably originating from the Hudson River. No spawning Atlantic Sturgeon were found in the Taunton River in May through June; therefore the authors concluded that the Taunton River was unlikely to have an annual spawning population of Atlantic Sturgeon. Buerkett and Kynard (1993) is the only documented record of sturgeon of either species in the Taunton River in recent years. Atlantic Sturgeon were not collected in the surveys in the Taunton River conducted by Bridges (1955), Curley et al. (1974), Hurley (1990), MRI (1992), or AECOM (2010). Acoustic tagging studies in other areas have raised questions about the efficiency of trawls and other past methods in collecting and detecting sturgeons in rivers. Massachusetts Division of Marine Fisheries currently maintains acoustic receivers in the Taunton River which should detect any tagged sturgeons that enter the area.

Atlantic Sturgeon has recently been collected in Rhode Island state waters. The RIDEM Trawl Survey was collected two Atlantic Sturgeon since 1997; one captured in Narragansett Bay in 1997 measured 85 cm TL and the other captured in Rhode Island Sound in October 2005 measured 130 cm TL (Greene et al. 2009). Based on the sizes recorded, these two fish were subadults. A fisherman in June 2004 fishing in Rhode Island state waters noted that the first three fathoms of towed gear held three juvenile Atlantic or Shortnose sturgeons (Anoushian 2004). The National Marine Fisheries Service (NMFS) observer program has also documented Atlantic Sturgeon bycatch in federal waters off the coast of Rhode Island (Greene et al. 2009).

The Greater Atlantic Regional Fisheries Office (GARFO) Master ESA species presence table which summarizes the best available information on Atlantic Sturgeon presence within coastal rivers, estuaries, and bays of the Greater Atlantic Region indicates that the Taunton River up to the convergence of the Town River and Matfield River provides foraging habitat, wherever suitable forage is present, for subadult (>76 cm to <150 cm total length) and adult (>150 cm total length) Atlantic Sturgeon (GARFO 2017). Narragansett Bay, throughout the bay, provides foraging habitat, wherever suitable forage is present, for subadult and adult Atlantic Sturgeon (GARFO 2017). No critical habitat was designated in the Taunton River or Narragansett Estuarine System for Atlantic Sturgeon for any of the five DPSs (82 FR 39160). Critical habitat in Massachusetts waters has been designated for the Gulf of Maine DPS in the Merrimack River from the Essex Dam downstream to where the main stem river discharges at its mouth into the Atlantic Ocean, and the New York Bight DPS in the Connecticut River from the Holyoke Dam downstream to the Connecticut state line (82 FR 39160).

4 Dissolved Oxygen Requirements

Oxygen is critical to the survival of many aquatic organisms; anoxic and hypoxic conditions have been shown to have profound negative impacts on coastal populations and entire ecosystems.

4.1 Atlantic Sturgeon

Atlantic Sturgeon is unusually sensitivity to low oxygen concentrations compared to other estuarine fishes (Secor and Gunderson 1998). The earliest life stages of Atlantic Sturgeon are the most sensitive to dissolved oxygen (DO) levels. Therefore, earlier life stages may avoid areas based on one DO level while older life stages (i.e. subadults or adults) may avoid areas based on a different DO level (82 FR 39160). Currently little information is known about larval Atlantic Sturgeon habitat, therefore no information is currently available on the dissolved oxygen habitat requirements for larvae (Greene et al. 2009). Dissolved oxygen is known to be an important habitat parameter for YOY and juvenile Atlantic Sturgeon (Greene et al. 2009). Secor and Gunderson (1998) compared Atlantic Sturgeon YOY survival under hypoxic (3 mg/L DO) and normoxic (7 mg/L DO) conditions at cold (19° C) and warm (26° C) water temperatures for 10 days. Mortality occurred only under hypoxic conditions, with a 21.7% mortality observed at 19° C and a 93.7% mortality observed at 26° C. Zero mortality occurred at normoxic conditions regardless of water temperature. Oxygen levels of 3 mg/L resulted in a threefold reduction in growth rate and a 50% reduction in sturgeon respiration rate compared to normoxic conditions (Secor and Gunderson 1998). Secor and Niklitschek (2002) suggested that bioenergetic and behavioral responses indicate that Atlantic Sturgeon YOY aged 30 to 200 days would experience a loss in growth in habitats with less than 60% oxygen saturation. This level corresponds to 4.3 mg/L to 4.7 mg/L at temperatures of 22°C to 27°C. Acute and chronic lethal effects were observed in Atlantic Sturgeon at DO levels of 3.3 mg/L at summertime temperatures (Secor and Gunderson 1998, Secor and Niklitschek 2002).

Niklitschek and Secor (2009) measured growth, food consumption, routine and postprandial metabolism, egestion, and survival responses of YOY (6 – 48 g) and yearling (100–300 g) Atlantic Sturgeon in an incomplete array of temperature, salinity and dissolved oxygen levels. Their results indicated that all three factors had a significant effect on major bioenergetic responses. Maximum growth and food consumption rates were observed above 70% DO saturation, at 20 °C, and between salinities of 8 and 15 ppt. A 70% DO saturation is equivalent to 7.9 mg/L at 12 °C, 6.7 mg/L at 20 °C. Postprandial metabolism was reduced and egestion increased under hypoxia (50% DO saturation), suggesting compensatory mechanisms aimed to reduce assimilation rates. The authors indicated that survival increased with DO saturation, and survival decreased with increasing salinities and temperatures. Estimated YOY mortality was two times higher at 30% DO saturation than at 40%, and four times higher than at 70% DO saturation. The results also indicated both additive and synergistic effects of temperature, salinity, and dissolved oxygen upon sturgeon ecophysiological responses. Niklitschek and Secor (2009) emphasized that percent DO saturation or partial pressure of DO are the biologically relevant factors for hypoxia, since these, rather than oxygen concentration, represent what physically determines fish oxygen uptake from the surrounding water.

Moberg and DeLucia (2016) presented a relationship between recruitment observations and DO in the Delaware River indicating that during years when recruitment was observed (2009, 2011, and 2014), minimum daily DO was above 5.0 mg/L in 90% of the observations. The median minimum daily DO during these years was > 6.0 mg/L during the spawning and egg and larval development periods (May - July). The Delaware River 7-day minimum flow remained above 4,000 cubic feet per second (cfs), more than five summer high flow events (>18,000 cfs) occurred, and the salt front remained downstream of spawning and early life stage development habitat. During the years when recruitment was not observed (2005-8, 2010, 2012, and 2013), median minimum daily DO was between 4.0 and 5.0 mg/L, and conditions were frequently < 4.0 mg/L. During the months of June through September of 2005-2014, all measurements taken when DO was < 4.0 mg/L occurred under low flow conditions (< 8,000 cfs). During the summer of 2010, the Delaware River experienced an extreme low flow event with several weeks below 4,000 cfs, and no summer high flow event occurred. DO concentrations during this event were measured as low as 3.2 mg/L, and the salt front covered and migrated upstream of spawning and early life stage development habitat. Flow in the Delaware River is influenced by reservoir operations, water withdrawals and climatic variability. The authors concluded that Atlantic Sturgeon of all life stages occurred throughout the freshwater portion of the Delaware River and that early life stages were there year round. Low (< 3.5 mg/L between 1966 - 1985 and < 5.0 mg/L through 2005) mean monthly DO concentrations between May and September was inhibiting successful development of early life stages. Current low flow summer river conditions influence the location of the salt front and the availability of suitable freshwater habitats for early life stages. Anticipated sea level rise and increased frequency and duration of drought conditions are expected to shift the salt front upstream in the Delaware River. They also identified the need for improved water quality standards and the use of best available technologies to improve DO conditions. Moberg and DeLucia (2016) recommended habitat conditions for successful Atlantic Sturgeon recruitment in the Delaware River consisting of the following thresholds: an instantaneous DO ≥ 5.0 mg/L, temperatures < 28 °C and salinity < 0.5 ppt. They also recommended that flow in the Delaware River during the summer months from June through September should be greater than 4,000 cfs when average daily DO < 5.5 mg/L.

The use of hatchery-reared Atlantic Sturgeon has been suggested as a useful tool to supplement of wild stocks and a restoration strategy. The U.S. Fish and Wildlife Service-Northeast Fishery Center at Lamar, Pennsylvania developed guidelines to hold and propagate Atlantic Sturgeon. The Atlantic Sturgeon culture manual recommends that first-feeding fry and fingerlings (about 0.3 grams to age-1 fish) should be maintained at dissolved oxygen levels of 8 mg/L or more.

Newly captured, stressed broodstock (adult) sturgeons are recommend to be maintained in holding tanks with dissolved oxygen levels greater than 80% saturation. For long-term captivity, broodstock sturgeons are recommended to be held in tanks containing dissolved oxygen levels greater than 6 mg/L (Mohler 2003).

The NMFS established safe environmental limits for capturing and handling Atlantic, Shortnose, Gulf, and Green Sturgeon to standardize safe, non-lethal research to benefit the recovery of these sturgeon species by allowing researchers gather vital information while minimizing the potentially negative impacts of research (Kahn and Mohead 2010). Research has revealed that for all sturgeon species survival is affected by a relationship between temperature, DO, and salinity and this vulnerability may be increased by the research-related stress of capture, holding, and handling (Kahn and Mohead 2010). NMFS recommends not capturing or handling Atlantic, Shortnose, and Gulf Sturgeon when DO concentrations are below 4.5 mg/L. Green Sturgeon should not be captured or handled when DO concentrations are below 5 mg/L. Additionally, NMFS recommends not sampling for Atlantic, Shortnose, or Gulf Sturgeon when temperatures exceed 28°C and Green Sturgeon should not be captured when water temperatures exceed 25°C (Kahn and Mohead 2010). NMFS also considered the percent oxygen saturation of water when establishing these recommendations; therefore NMFS recommends not sampling for Atlantic, Shortnose, or Gulf Sturgeon when oxygen saturation is below 55% or Green Sturgeon when oxygen saturation is below 58%. Sampling at higher temperatures or lower DO levels may be possible if the percent oxygen saturation in water is maintained at these levels (Kahn and Mohead 2010).

4.2 Other Sturgeon Species

Research has revealed that for all sturgeon species survival is affected by a relationship between temperature, DO, and salinity (Jenkins et al. 1993, Secor and Gunderson 1998, Secor and Niklitschek 2002). Since there is limited DO information available for some Atlantic Sturgeon life stages the use of DO tolerances for other sturgeon species may provide some guidance.

Shortnose Sturgeon (*Acipenser brevirostrum*)

Shortnose Sturgeon is more tolerant of higher water temperatures than Atlantic Sturgeon (Secor and Niklitschek 2001). Campbell and Goodman (2003) considered 29 °C a stressful temperature for this Shortnose Sturgeon, whereas Atlantic Sturgeon becomes stressed at a lower temperature of 26 °C (Secor and Gunderson 1998). Campbell and Goodman (2003) investigated acute sensitivity of juvenile Shortnose Sturgeon to low dissolved oxygen concentrations, the study indicated that the 24-hour LC_{50} for 77 day old fish was 2.7 mg/L (32% saturation) at 25 °C and 2% salinity and for 104 day old fish, 2.2 mg/ L (26% saturation) at 22 °C at 4% salinity. The 24-hour, 48-hour, and 72-hour LC_{50} values were also 2.2 mg/ L (28% saturation) for 134 day old fish at 26 °C and 4.5% salinity. The LC_{50} for 100 day old fish was 3.1 mg/ L at 30 °C and 2% salinity (Campbell and Goodman 2003). Based on these findings reported in Campbell and Goodman (2003), EPA (2003) calculated DO concentrations they believed would be protective of sturgeon exposed to both non-stressful and stressful temperatures and estimated a DO concentration of 4.3 mg/L should be protective under stressful temperatures. The EPA (2003) recognized that the

LC_{50} DO concentrations reported in Campbell and Goodman (2003) were not instantaneous but occurred within the first 2 to 4 hours of the tests. However, they concluded using their estimated value of 4.3 mg/L as an instantaneous value would be more protective for the species.

In acute 6-hour hypoxia experiments, Jenkins et al. (1993) observed an 86 - 100% mortality for 25 - 64 day old YOY and an 12-20 % mortality in 100-310 days old juveniles exposed to 2.5 mg/L DO at 22.5 °C (30% saturation). Short-term exposure to 3.0 mg/L (35% saturation) resulted in 18 - 38% mortality for 20 - 77 days old juveniles (Jenkins et al. 1993, Secor and Niklitschek 2002). No mortality was observed when DO concentrations were at or above 4.0 mg/L (Jenkins et al. 1993).

Niklitschek (2001) reported that optimal growth for YOY Shortnose Sturgeon occurred at 70% oxygen saturation at a temperature of approximately 20°C, although differences may exist between populations in different geographical regions. The author observed substantial reductions in YOY Shortnose Sturgeon routine metabolism, consumption, feeding metabolism, growth, and survival at 40% DO saturation compared to 70% saturation. At 20°C, 40% DO saturation (3.3 mg/L) yielded a 30% reduction in growth, a 27% reduction in consumption, and 17% reduction in routine metabolism for Shortnose Sturgeon compared to 70% DO saturation. At 27 °C, 40% DO saturation (2.9 mg/L), produced a 69% reduction in growth, a 45% reduction in consumption, and 21% reduction in routine metabolism (Niklitschek 2001, Secor and Niklitschek 2002). These bioenergetic and behavioral responses show that YOY Shortnose Sturgeon (about 30 to 200 days old) will experience lost production in habitats with less than 60% oxygen saturation; this corresponds to DO concentrations of 4.3 - 4.7 mg/L at temperatures ranging from 22° to 27 °C (Secor and Niklitschek 2002).

Eurasian Sturgeons (*Acipenser güldenstadtii, A. baeri, A. stellatus and the hybrid Huso huso x A. ruthensus*)

The basal metabolism of the Stellate Sturgeon (*Acipenser stellatus*), was measured over a range of temperatures and oxygen levels, and increases with temperature but is only affected by oxygen at lower oxygen levels, above which there is little response. On the metabolic response curve to DO, the point of inflection is called the critical concentration. Oxygen levels below that point will constrain metabolism, growth, swimming activity, and feeding rate (Secor and Niklitschek 2002). At higher temperatures as basal metabolism increases due to increased temperature, the critical DO concentration becomes higher, and will outpace oxygen availability due to decreased oxygen solubility at higher water temperatures (Secor and Niklitschek 2002). Critical DO concentrations for Eurasian sturgeons ranged between 25-60% saturation, increasing with temperature. At 20°C, the critical DO concentration was 3.6 mg/L (42% saturation), and at 24°C, critical concentration was 4.5 mg/L (54% saturation; Secor and Niklitschek 2002).

5 Designated Critical Habitat for Atlantic Sturgeon

Critical habitat for the Endangered New York Bight, Chesapeake Bay, Carolina and South Atlantic DPSs and the Threatened Gulf of Maine DPS of Atlantic Sturgeon was designated on August 17, 2017 (82 FR 39160). The final rule states that the NMFS *determined that a key* *conservation objective for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs is to increase the abundance of each DPS by facilitating increased successful reproduction and recruitment to the marine environment. We know that each of these DPSs is at a low level of abundance and that successful reproduction and recruitment, which are essential to the conservation of the species, occur in a limited number of rivers for each DPS. Based on the best scientific information available for the life history needs of the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs, the physical features essential to the conservation of the species and that may require special management considerations or protection are:…*

> *…(4) Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support:*
>
> > *(i) Spawning;*
> >
> > *(ii) Annual and interannual adult, subadult, larval, and juvenile survival; and*
> >
> > *(iii) Larval, juvenile, and subadult growth, development, and recruitment (e.g., 13 °C to 26 °C for spawning habitat and no more than 30 °C for juvenile rearing habitat, and 6 milligrams per liter (mg/L) dissolved oxygen (DO) or greater for juvenile rearing habitat)….*

NMFS *determined that the key conservation objectives for the Carolina and South Atlantic DPSs of Atlantic Sturgeon are to increase the abundance of each DPS by facilitating increased survival of all life stages and facilitating adult reproduction and juvenile and subadult recruitment into the adult population. We determined the physical features essential to the conservation of the species and that may require special management considerations or protection, which support the identified conservation objectives, are:…*

> *…(4) Water quality conditions, especially in the bottom meter of the water column, between the river mouths and spawning sites with temperature and oxygen values that support:*
>
> > *(i) Spawning;*
> >
> > *(ii) Annual and inter-annual adult, subadult, larval, and juvenile survival; and*
> >
> > *(iii) Larval, juvenile, and subadult growth, development, and recruitment. Appropriate temperature and oxygen values will vary interdependently, and depending on salinity in a particular habitat. For example, 6.0 mg/L DO or greater likely supports juvenile rearing habitat, whereas DO less than 5.0 mg/L for longer than 30 days is less likely to support rearing when water temperature is greater than 25 °C. In temperatures greater than 26 °C, DO greater than 4.3 mg/L is needed to protect survival and growth. Temperatures of 13 to 26 °C likely to support spawning habitat.*

Critical habitat for the Gulf of Maine, New York Bight, and Chesapeake Bay DPSs does not include a specific threshold for dissolved oxygen levels for juvenile, subadult, or adult Atlantic Sturgeon but states that the temperature, salinity, and oxygen values combined must support spawning, survival, growth, development, and recruitment. The NMFS stated in response to commenters that it did not specify optimal or suboptimal dissolved oxygen levels because there is not one single DO level or temperature range that is best for Atlantic Sturgeon in terms of habitat avoidance (82 FR 39160). Temperature, salinity and dissolved oxygen are inter-related water quality variables. Dissolved oxygen concentrations in water can fluctuate due to a number of factors including water temperature (e.g., cold water holds more oxygen than warm water) and salinity (e.g., the amount of oxygen that can dissolve in water decreases as salinity increases; 82 FR 39160). Dissolved oxygen levels that support growth and development will be different at different combinations of water temperature and salinity. Similarly, the dissolved oxygen levels that Atlantic Sturgeon would be expected to avoid would also vary based on the water temperature and salinity (82 FR 39160). The NMFS also recognized that dissolved oxygen tolerance changes with age, and as a result the conditions that support growth and development, and the dissolved oxygen levels that would be avoided would also change. The NMFS stated that this combination of factors makes it so that a single set of dissolved oxygen, water temperature and/or salinity conditions as for any of the DPSs cannot be identified as optimal or suboptimal (82 FR 39160). NMFS provided an example of a temperature and dissolved oxygen combination for juvenile rearing habitat of no more than 30 °C and 6 mg/L DO or greater for juvenile rearing habitat. The NMFS stated that the use of "e.g." in the regulatory text informs the reader that the DO level and water temperature are provided only as guidance, and these are not the only values for either DO or temperature that are suitable for all Atlantic sturgeon age classes (82 FR 39160).

The NMFS designated the instantaneous minimum DO levels needed to protect Atlantic Sturgeon in the Carolina and South Atlantic DPSs at 4.3 mg/L in water temperatures greater than 26 °C. NMFS stated that critical habitat physical and biological features are essential to the conservation of a species, not just its survival, and a metric that is "protective" in a broad, water quality context may still lead to injury and even mortality of individual organisms. Therefore, critical habitat physical and biological features may not be the best metric to foster conservation (82 FR 39160). In determining the instantaneous minimum DO levels, the NMFS considered 26 °C to be the stressful temperature for Atlantic Sturgeon based on Secor and Gunderson (1998), and a DO concentration of 4.3 mg/L to be protective under stressful temperatures based on EPA (2003). The EPA (2003) calculated DO concentrations they believed would be protective of sturgeon exposed to both non-stressful and stressful temperatures based on the findings in Campbell and Goodman (2003) for Shortnose Sturgeon. The EPA (2003) recognized that the LC_{50} DO concentrations reported in Campbell and Goodman (2003) were not instantaneous; however, they concluded using their estimated value of 4.3 mg/L as an instantaneous value would be more protective for the species. The NMFS believed that more conservative values were appropriate to promote conservation of Atlantic Sturgeon since the EPA estimates produced thresholds that still led to some level of injury or death (82 FR 39160).

6 Topics for Discussion

1) MassDEP is considering the use of percent saturation for the DO criteria instead of concentration (mg/L). Percent saturation is a biologically relevant factor for hypoxia and represents what physically determines fish oxygen uptake from the surrounding water. It is expected to provide a better criterion for the ranges of temperatures and salinity that occur and are expected to occur in Mount Hope Bay and the Taunton River. Can the EPA provide any current guidance or recommendations for using percent saturation instead of concentration for DO criteria?

2) MassDEP intends to be protective of Atlantic Sturgeon using information from published literature and results from the DO tolerance analysis of the resident assemblage, which includes Atlantic Sturgeon as a potential resident in the study area. Protective DO criteria should allow sturgeons to naturally reoccur in the study area.

3) In the review of proposed DO criteria, how will the EPA apply the critical habitat designation under the Endangered Species Act to locations where Atlantic Sturgeon could occur?

7 References

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Appendix A. Summary of Atlantic Sturgeon (*Acipenser oxyrinchus oxyrinchus*) environmental habitat parameters.

Life stage	Size[a]	Description[a]	Habitat	Occurrence	Dissolved Oxygen	Temperature (°C)	Salinity (ppt)
Eggs		Fertilized or unfertilized	Flowing water of rivers along the Atlantic coast. Eggs are adhesive and attach to hard substrate including gravel and cobble[b].	May - June in Massachusetts waters[c]	NA	Reported: Hatching occurs in 94 to 140 hours at water temperatures of 20° and 18°, respectively[b] Culture: 20-21 optimal[d]	Reported: Freshwater - found upstream of the salt front[b,e]
Larvae	< 30 mm TL	Nourished by yolk sac, negative phototaxis	Same habitat as eggs[b]	May - June in Massachusetts waters[c]	Culture: 8 mg/L or greater[d]	Reported: 15.0 - 24.5[c] Culture: 15.0 - 19.0[d]	Reported: 0 - 2.2[f]
YOY	< 41 cm TL	Fish that are > 3 months and < 1 year old, capable of capturing and consuming live food	Natal river over rocks, cobble, sand, and mud or transitional substrates[b]	August - April (based on description and larval occurrence in Massachusetts waters)	Culture: 8 mg/L or greater[d] Optimal: above 70% saturation[g] Acute and chronic lethal effects: ≤ 3.3 mg/L[h,i]	Sub-lethal: > 28[b,j]	0 - 15[g]
Juveniles	> 41 cm to <76 cm TL	Fish that are at least 1 year old and are not sexually mature, they do not make coastal migrations	Natal river over rocks, cobble, sand, and mud or transitional substrates[b]	Year round in natal river[b]	Optimal: above 70% saturation[g] Acute and chronic lethal effects: ≤ 3.3 mg/L[h,i]	Tolerate: 3 - 28, Optimal: about 20, Sub-lethal: > 28[b,j]	Reported: 0 - 27.5, Optimal: about 10[b]
Subadults	> 76 cm to < 150 cm TL	Fish that make coastal migrations but are not sexually mature	Estuarine and marine waters[b]	Year round[c]	NA	Sub-lethal: > 28[j,k]	Reported: 0 - marine waters[b]
Adults	> 150 cm TL	Fish that are sexually mature	Estuarine and marine waters, Spawning occurs in freshwater rivers[b]	Year round[c]	Culture: > 6 mg/L[d]	Reported in temperatures as high as 33.1 in South Carolina[b]	Reported: 0 - marine waters[b]

NA indicates not available.

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